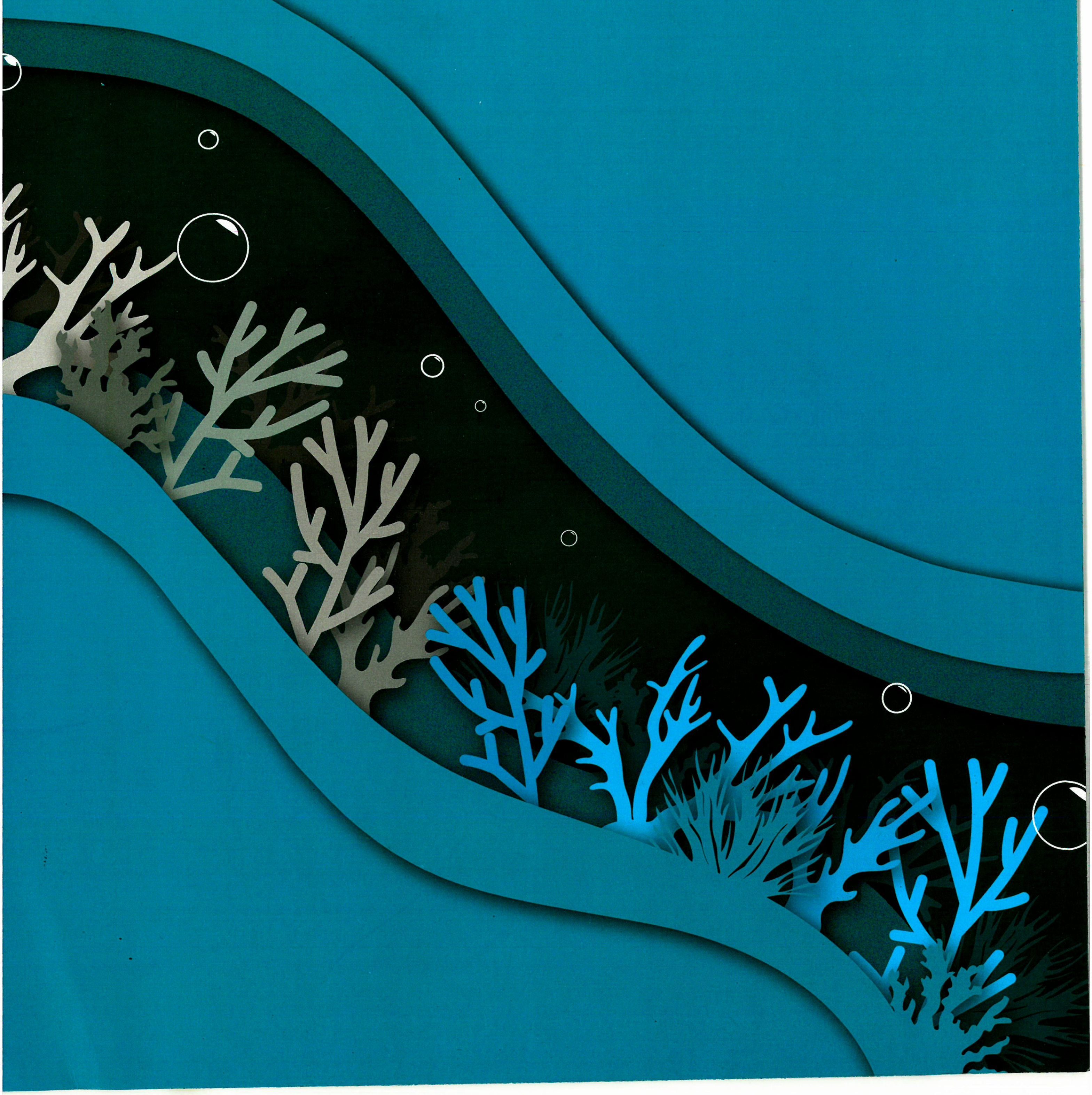
CRITICAL CARE MEDICINE 1

Marrow SS Medicine



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Dr. Riddhi Kundu holds the European Diploma in Intensive Care (EDIC) and completed a Critical Care Fellowship at the University Health Network, Toronto. With 40+ publications, he reviews for three PubMed journals and is an ACC/AHA-certified BLS & ACLS instructor. He specialises in transplant critical care, ECMO, obstetric, and trauma. A graduate of Burdwan Medical College, he earned his MD in Anaesthesiology and DM in Critical Care Medicine from AIIMS, New Delhi.

Critical Care Medicine

Volume - 1

MARROW
Super Speciality

Instructions

- The notes must be used in conjunction with the Marrow SS Medicine videos and should not be considered standalone material.

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- This set contains notes of all main videos published in the app until Jan 2025. You can find notes for any additional videos published after this date within the app under the videos section.

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Contents

Volume - 1

Basics of Critical Care Medicine

Respiratory Disorders

Electrolyte and Acid Base Disorders

Shock

Cardiac Critical Care

Infections

Volume - 2

Renal Disorders

Other Topics

HEMODYNAMIC MONITORING

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Cardiovascular organ dysfunction : 2nd most common organ dysfunction.

Continuously observing changes in physiologic variables :

- To monitor organ function.
- For prompt therapeutic interventions.
- To evaluate response to therapeutic interventions.

monitoring per se does not improve patient outcomes.

Timely applied right interventions can cause imrpovement in outcomes.

Assessing global and regional perfusion

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Initial steps :

1. Clinical assessment.
2. Basic monitoring and assessment of global perfusion.
3. Preload monitoring and fluid responsiveness.

Advanced monitoring measures :

1. Cardiac output monitoring.
2. Assessment of cardiac contractility.
3. Assessment of tissue perfusion.

Step 1 : Clinical assessment.

- Thirst.
- Cold extremities.
- Poor peripheral pulses.
- Impaired capillary refill.

→

- Tachypnoea, tachycardia.
- Confusion.
- Altered skin perfusion.
- Oliguria.

Skin mottling :

Important predictor of adverse outcome.

- Score 0 : No mottling.
- Score 1 : Small area of mottling, localised to centre of knee.
- Score 2 : modest mottling area that does not extend beyond superior border of kneecap.
- Score 3 : mild mottling area that does not extend beyond the mid-thigh.
- Score 4 : Severe mottling area, not going beyond the groin fold.
- Score 5 : Extremely severe mottling area, extending beyond groin fold.

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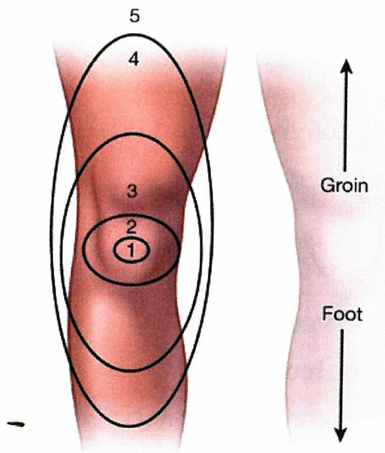
Mottling score

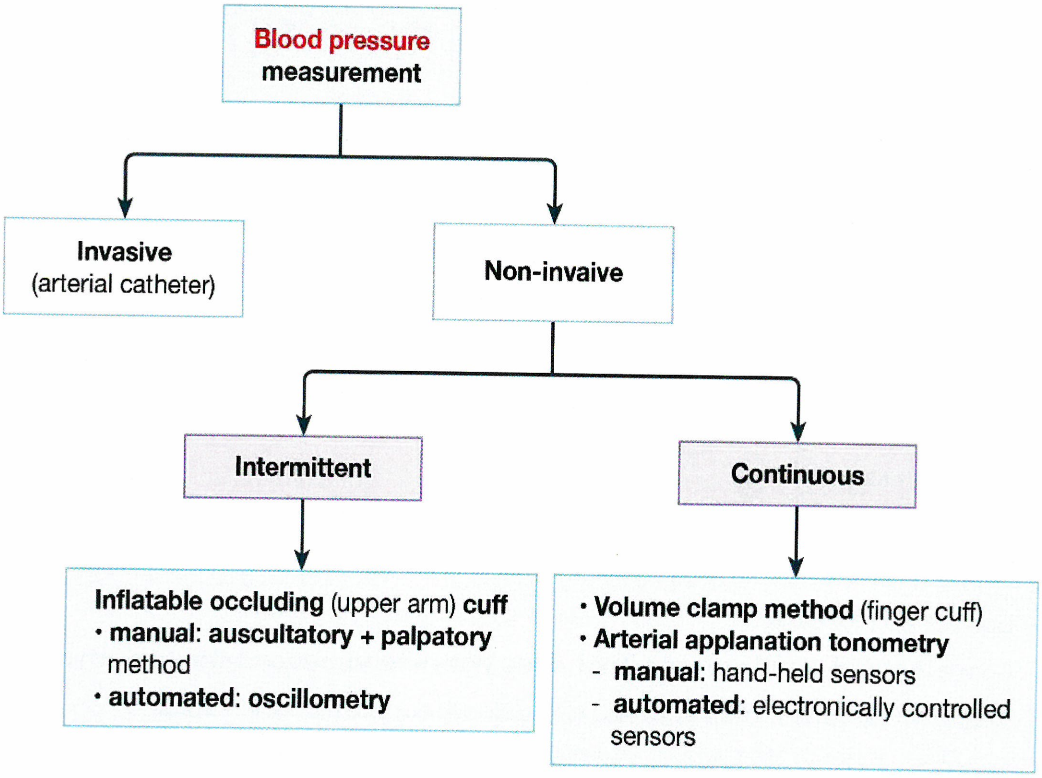


GRADE 2 MOTTLING

Step 2 : Basic monitoring and assessment of global perfusion :

- 12 lead ECG.
- Blood pressure : Non invasive and invasive.
- Pulse oximetry (SpO_2).
- Lactate levels.
- Biochemical variables.

Blood pressure monitoring :



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NIBP : Intermittent.

Manual intermittent	Automated intermittent
• Described by Korotkow in 1905. • Sphygmomanometer, cuff, and stethoscope needed. • Auscultating sounds generated by turbulent arterial blood flow beyond cuff. • Systolic : First Korotkoff sound. • Diastolic : Before disappearance.	• Based on oscillometry. • Cuff is coupled to an oscillometer. • The cuff inflated above systolic pressure → Then gradually deflates. • MAP : pressure at peak amplitude of arterial pulsations. • SBP & DBP : Derived from proprietary formulas (Rate of change of pressure pulsations).

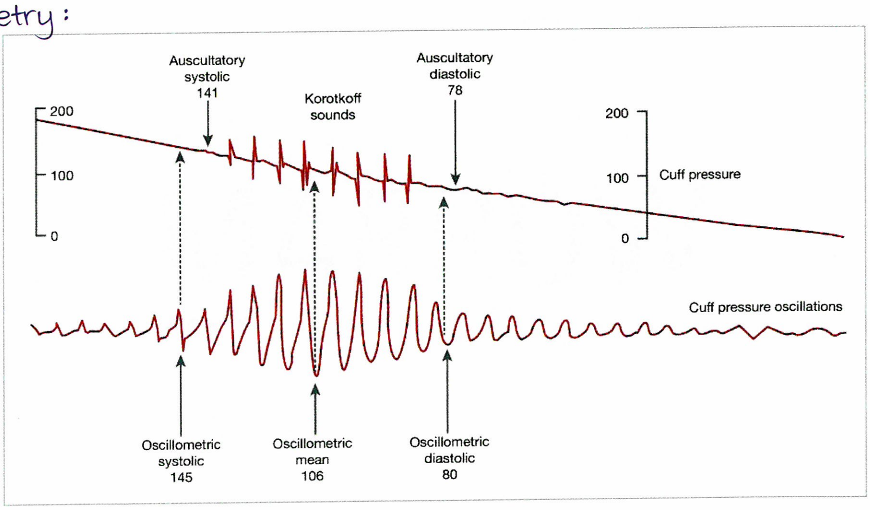
Cuff Size :

- Bladder length : 80% of arm circumference.
- Bladder width : 40% of arm circumference.
- Midline of cuff bladder should be positioned over the arterial pulsation.

Patient	Recommended cuff size
Adults (by arm circumference)	
22 to 26 cm	12 x 22 cm (small adult)
27 to 34 cm	16 x 30 cm (adult)
35 to 44 cm	16 x 36 cm (large adult)
45 to 52 cm	16 x 42 cm (adult thigh)

BP cuff size

Comparison of blood pressure measurements via Korotkoff sounds and oscillometry :



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Non invasive :

CNAP : Continuous noninvasive arterial pressure.

Volume clamp method (finger cuff) :

- Inflatable finger cuff with infrared
- plethysmography & monitor.
- Adjusts its pressure multiple times per second to keep volume in finger artery constant.
- Produce a brachial arterial waveform.

B

T- line system :

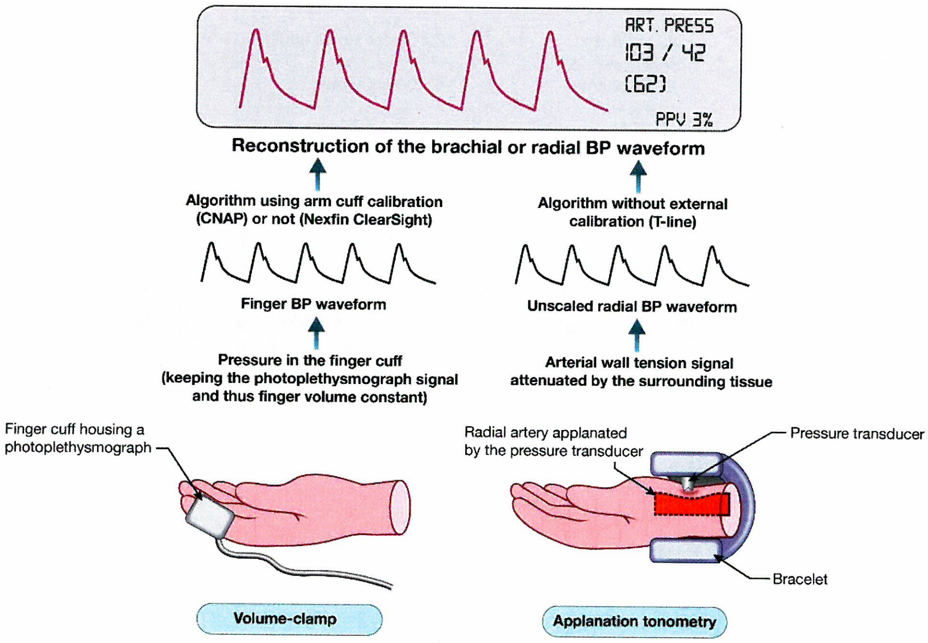
Based on applanation tonometry.

T- line system: Based on applanation tonometry

- Radial artery applanation :
- A pressure sensor applied over radial artery :
- Gently compresses artery : Applanates.
- The sensor is automatically moves over radial artery until optimal waveform is recorded.

- External applanation leads to reconstruction of BP waveform.
- Mean BP measured directly (optimal waveform).

Oscillometric, volume-clamp, and applanation tonometry technol arterial BP



Invasive blood pressure :

- Gold standard for BP monitoring :
  - Arterial cannulation.
  - Continuous pressure transduction.
  - Waveform display.

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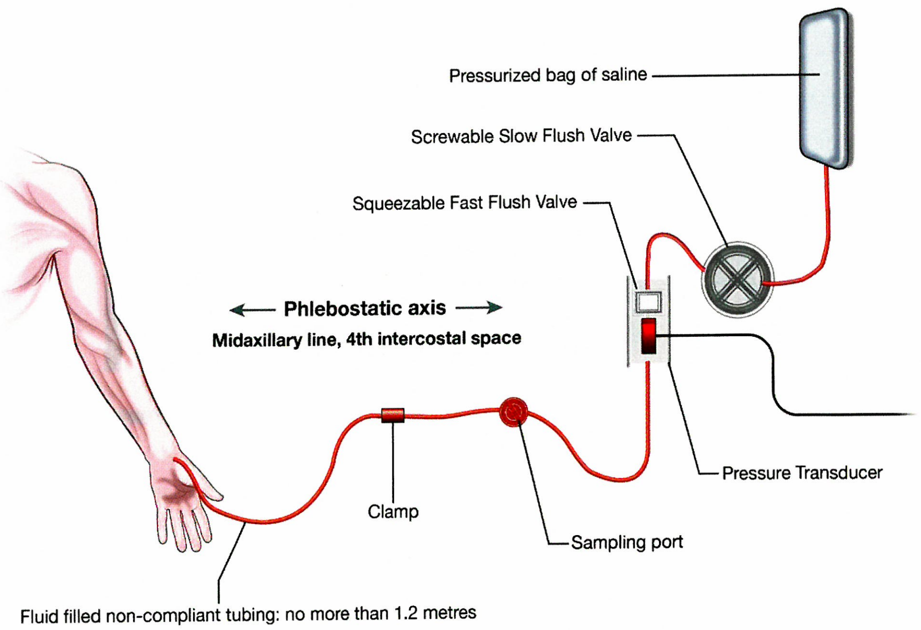
- Conventions :
  - Pressures expressed as mmHg.
  - Referenced to phlebostatic axis.
  - Zeroed to ambient pressure.

Arterial Line Transducer Setup



Indications :

- Unstable blood pressure/severe hypotension.
- Use of rapidly acting vasoactive drugs : Vasodilators, vasopressors, inotropes.
- Frequent sampling of arterial blood.

Relative contraindications for invasive arterial pressure monitoring :

- Anticipation of thrombolytic therapy.
- Severe peripheral vascular disease preventing catheter insertion.
- Vascular anomalies : AV fistula, local aneurysm, local haematoma, Raynaud's disease.
- Lack of collateral blood flow distally (Eg : Radial artery previously used for coronary artery bypass surgery).

Modified Allen test :

- Used to assess adequacy of collateral circulation.
- Reduced collateral flow when palm remains pale >6 to 10 seconds.
- Disadvantage : Sensitivity (70-80%).

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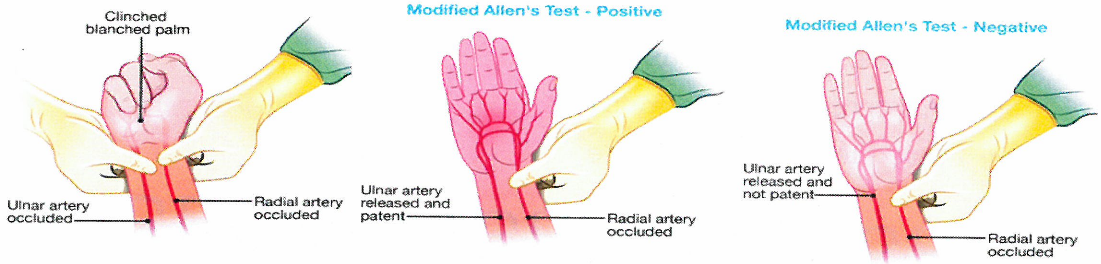


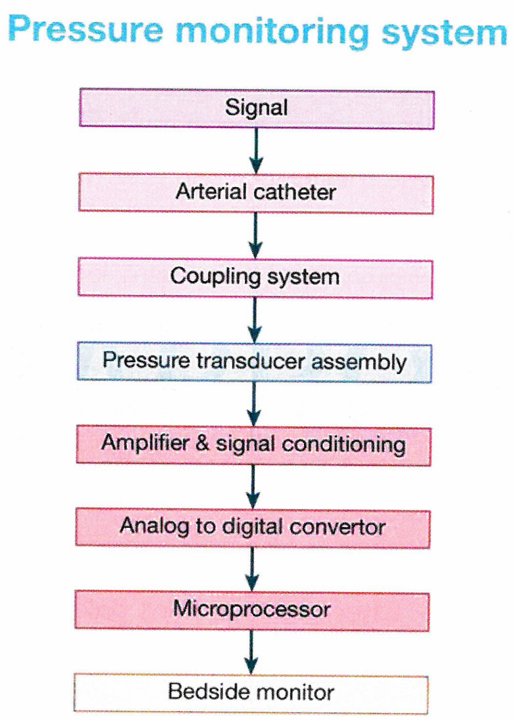
Common sites :

1. Radial.
2. Femoral.
3. Dorsalis pedis.
4. Posterior tibial.

Complications of direct arterial pressure monitoring :

- Distal ischemia, pseudoaneurysm, arteriovenous fistula.
- Hemorrhage.
- Arterial embolization.
- Infection.
- Peripheral neuropathy.
- misinterpretation of data.
- misuse of equipment.

Pressure monitoring system :



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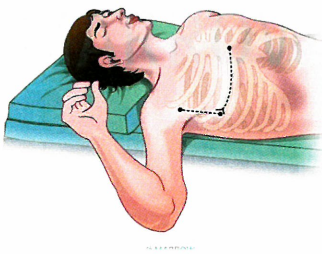
Zeroing & levelling :

- Levelling : At level of the right atrium, we establish the 0 baseline..
- Zeroing : Opening the transducer stopcock to atmosphere.
- Stopcock at level of midaxillary line 4th ICS : Flavostatic axis.
- With the stopcock open, monitor displays 0.

Zeroing and Levelling



Physics of arterial waveform

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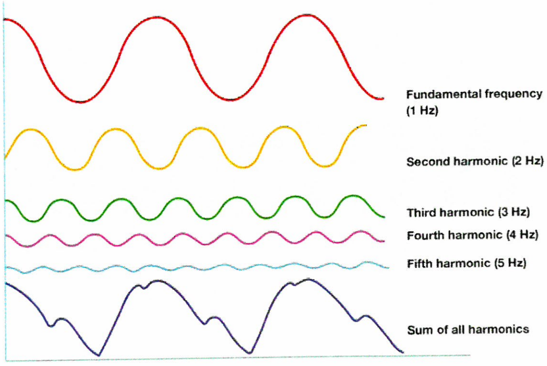
Fourier analysis of complex waveform :

Arterial waveform is a composite of many waveforms of increasing frequencies (Harmonics).

8-10 harmonics.

Fourier analysis of a complex waveform



Natural frequency :

Frequency at which a system oscillates.

$$\text{Natural frequency } f_n = \frac{1}{2\pi}\sqrt{\frac{\pi D^2}{4\rho L}\cdot\frac{\triangle P}{\triangle V}}$$

Dependent on :

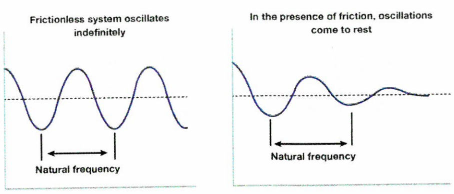
- maximum diameter.
- minimum length.
- Low compliance.

The coupling system :

Fluid between artery and transducer acts as simple harmonic oscillator :

- Analogous to a pendulum.
- When the pendulum is displaced, it undergoes simple harmonic motion it oscillates around the equilibrium point.

The Coupling system



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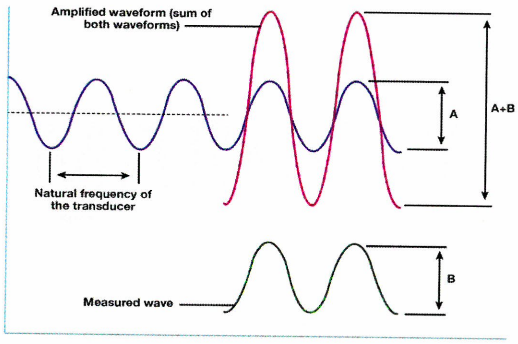
- Resonance : Amplification of a signal.
  Occurs when it's frequency is close to natural frequency of a system.

The Coupling system



- If natural frequency of pressure transducer matches with each peak of arterial pressure wave → Increase amplitude of the measured values.
- Transducer system must have a natural frequency well above the 8th harmonic frequency of a rapid pulse : >24Hz (Taking HR upto 180/min).

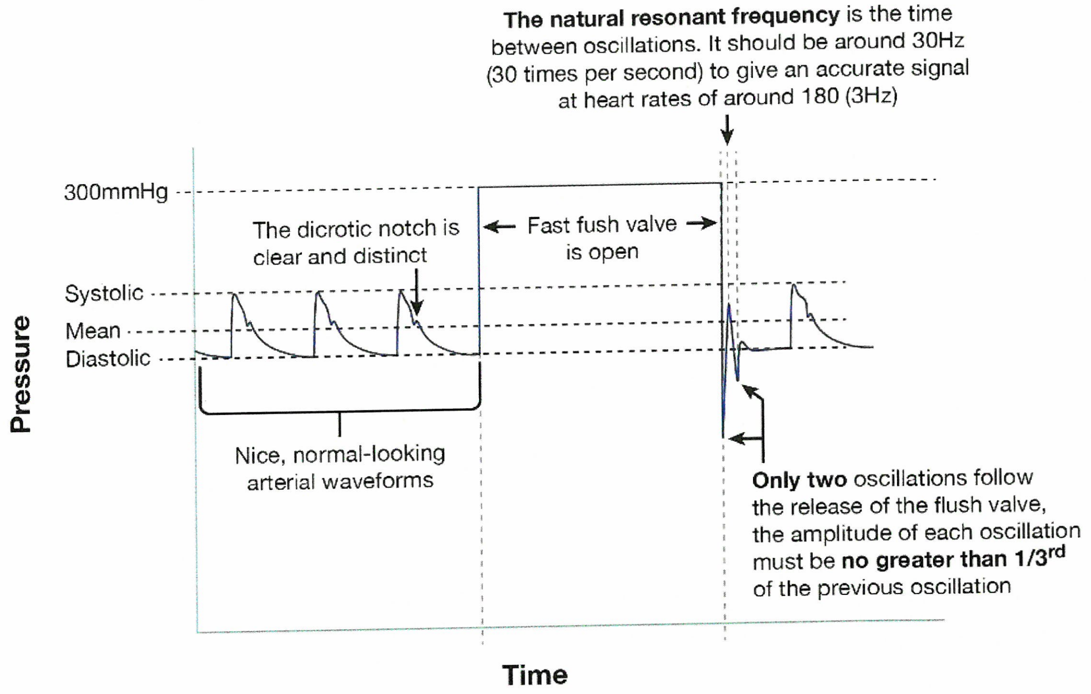
Damping :

- Absorption of energy (Amplitude) of oscillations :
  - Decreases amplitude of waves.
  - Reduces natural frequency of a system.
- Adequately damped → Amplitude should not change due to resonance.
- Diameter of the tubing has the greatest effect on damping.
- Damping increases by third power of any decrease in tubing diameter.

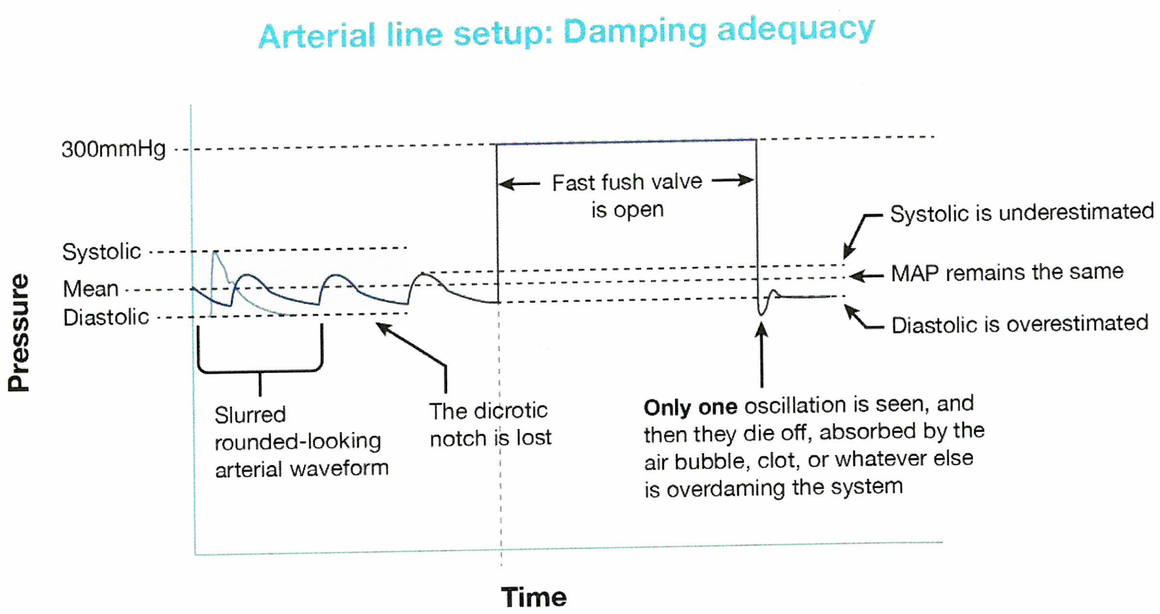
Dynamic response :
Ability of the system to accurately reproduce hemodynamic waveform.

Damping coefficient :
To assess how quickly an oscilating fluid filled system comes to rest.
Test : Fast flush test.

Arterial line setup : Damping adequacy.



Over damped system :



Occurs in cases of : Clots, Kinks, air bubbles, low compliant tubings, loose connection.

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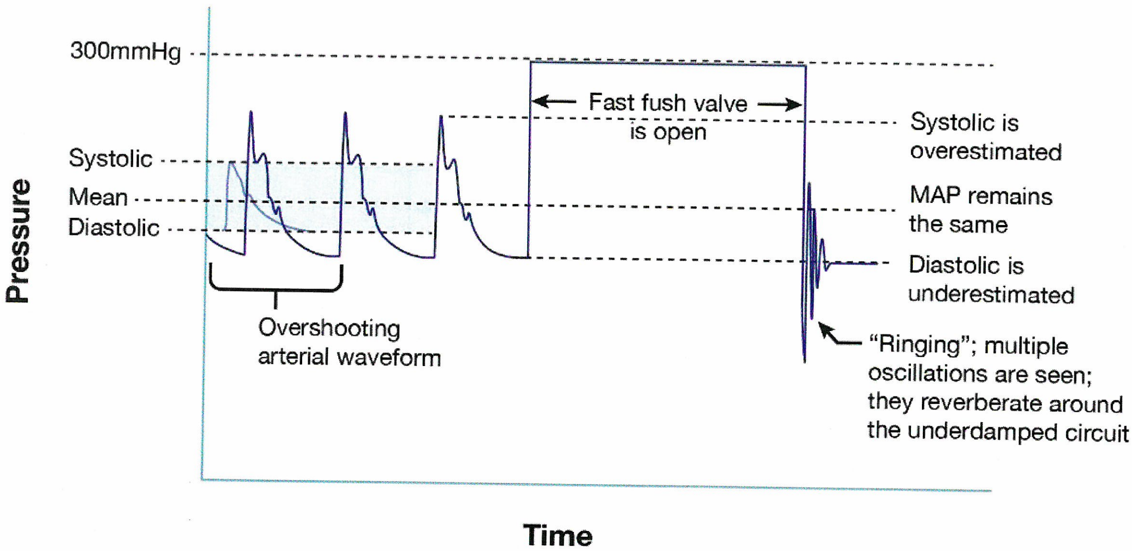
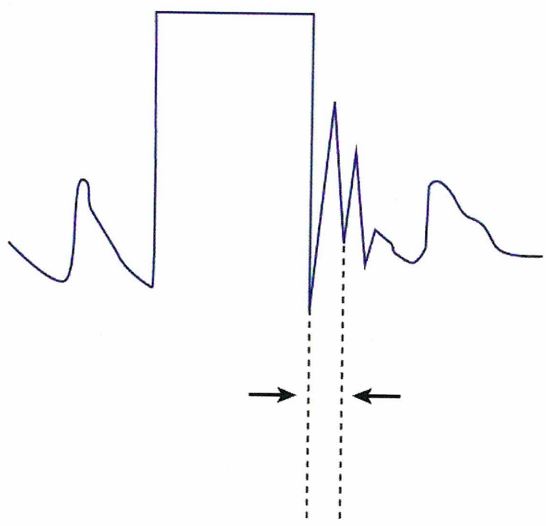
Underdamped system :



Occurs in : Long tubing, hyperdynamic circulation, tachycardia, hypertension, atherosclerosis.

Determining frequency of a system :

Determining f_n



$$f_n = \frac{\text{Paper speed (mm/sec)}}{\text{T (time of one cycle) mm}}$$

If t = 1.2 mm, f_n = 20Hz

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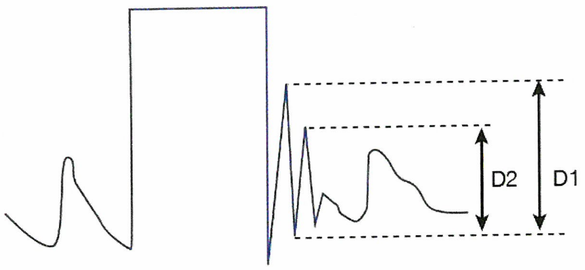
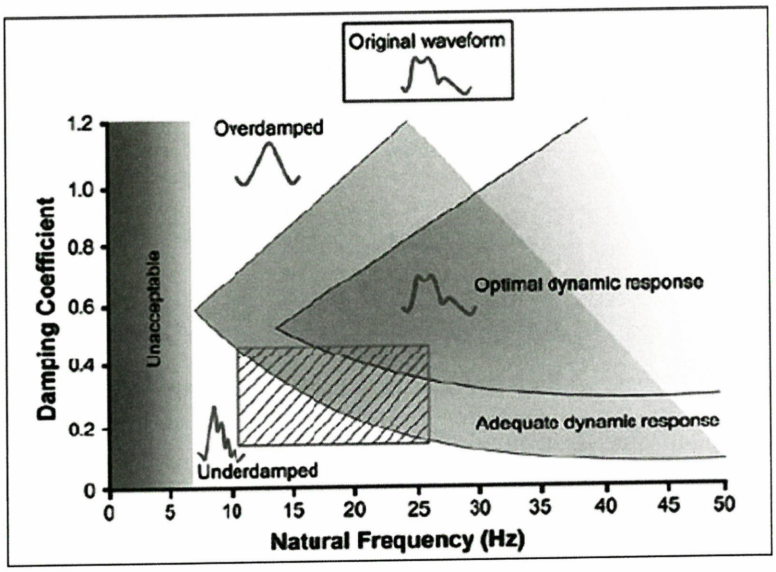
Amplitude ratio :

Height of waves generated following a fast flush test.



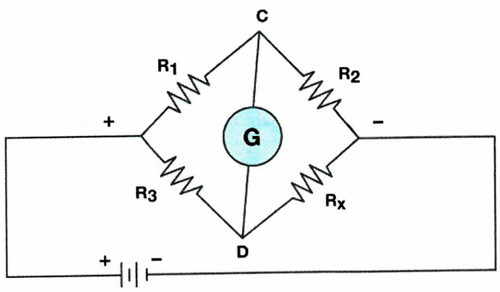
Amp Ratio (D2/D1)	Damping coefficient
0.9	0.034
0.8	0.071
0.7	0.113
0.6	0.160
0.5	0.215
0.4	0.280
0.3	0.358
0.2	0.456
0.1	0.591
0.05	0.690

Arterial line setup : Dynamic response.



Pressure transducer :

- A transducer is a device which converts energy from one form to another : Pressure into electrical energy.
- It acts on the principle of Wheatstone bridge.
- Wheatstone bridge : Electrical circuit with one unknown resistor.



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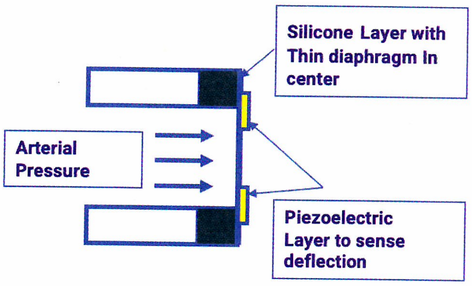
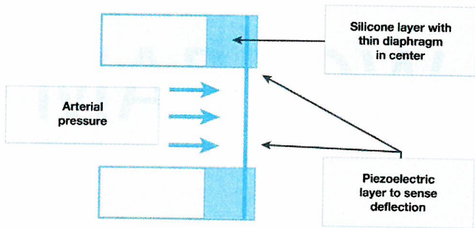
Mechanism :

- Piezoresistive strain gauges is used to complete the circuit.
- Wheatstone bridge is used to measure the unknown resistance (Of strain gauge).
- Resistance of unknown resistor is determined by pressure.



Pressure Transducer



Components of arterial pulse waveform

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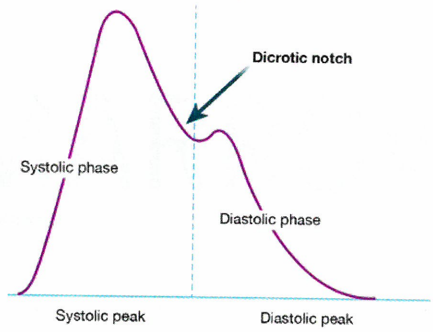
Components :

i. Systolic phase :
- Rapid increase in pressure to a peak.
- Begins with opening of aortic valve.
- Corresponds to LV ejection.

ii. Dicrotic notch :
Closure of aortic valve.

iii. Diastolic phase :
Run-off of blood into peripheral circulation.

Dicrotic notch



Arterial pressure waveform

Analysis :

- On ECG, R wave signals beginning of systole.
- Systolic upstroke does not occur immediately following systole. There is 160-180 millisecond delay.

ECG and Arterial Pulse Waveform